CARPET WEAR TESTING MACHINE

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ABSTRACT

A machine for testing the resistance to wear of carpets and similar floor coverings when they are subjected to definite wearing forces under controlled conditions has been developed at the National Bureau of Standards. The forces are chosen to produce the bending, slipping, twisting, and compression of the pile which takes place when a carpet is walked upon.

A circular sample of the carpet to be tested is tacked on a turntable which is brought to bear against two leather-covered wheels. One of the wheels is driven by a motor and in turn drives the turntable. The other wheel is used as a brake to produce slipping of both wheels on the carpet as it rotates. A vacuum cleaner removes the material which is worn off. The wear on the carpet is produced by a downward force, a horizontal stress and a slight twisting motion. They have definite values and may be varied. The rate of wear is evaluated by measuring the change in thickness of the pile of the carpet with a sensitive thickness gage as the test proceeds.

The machine can be used to test the relative durability of carpets under definitely specified conditions. Whether the results are a satisfactory measure of probable relative durability of carpets in service has not been determined. The machine should be useful for studies of the effect of various factors on carpet wear and for studies of the relation between the composition and construction of carpets and their resistance to wear.

CONTENTS

I. INTRODUCTION

Carpets and similar floor coverings are expected to be not only attractive in appearance and feel, but to be resistant to wear. The user of carpets is interested in the relative durability of the different types, and the manufacturer should know the relative durability of carpets of various compositions and constructions in order better to meet the varying requirements of his customers.

Practical service tests of carpets are expensive, time consuming, and difficult to control. Yet no one laboratory test can simulate all of the conditions to which carpets may be subjected in service. For these reasons, it was considered advisable as a first step in the study of

carpet wear to devise a machine in which samples of carpet could be subjected to definite wearing forces that may be varied at will under controlled, reproducible conditions.

This paper describes such a machine [1] and gives the results of some tests made with it. The reproducibility of the results is demonstrated and the effect of varying the applied forces is shown.

Under ordinary service conditions much of the wear of carpets appears to be caused by walking. In the act of walking the applied force is usually in a forward direction at the beginning of the step. It changes gradually through a vertical to a backward direction at the end of the step. In addition, walking is often accompanied by a slight horizontal rotary motion of the foot. The horizontal component of the initial foward force bends the pile of the carpet forward, while its vertical component compresses the pile. Toward the end of the step, the applied force tends to increase the bending of the pile yarns and to push them backward. Throughout the step there is a certain amount of slippage between the shoe and the carpet, first forward and then in the reverse direction. The horizontal rotary motion tends to twist the pile yarns and thus to increase the stresses on the fibers. As a result of this bending, slipping, twisting, and compression of the pile the fibers are gradually weakened, broken off, or pulled out of the base of the carpet.

The wear of carpets under certain conditions of service may be attributable to other causes. An accumulation of gritty material in a carpet may abrade and cut the fibers. Excessive use of cleaning devices may result in unnecessary wear. Impact forces may be one of the causes of the rapid wear of carpets on stairways. Atmospheric influences, such as very low or very high humidity or injurious fumes, may contribute to the wear of carpets in certain localities or under certain conditions of use.

These considerations led to the construction of a machine capable of subjecting small samples of carpet repeatedly to the wearing forces which appear to predominate when carpets are walked upon, namely, downward, horizontal, and twisting stresses with slippage. The machine is arranged so that the magnitude of these forces is known and can be varied. The material worn from the carpet during the test is removed by suction in order to eliminate its action.

The need for a method of measuring carpet wear is evident. Change in appearance does not lend itself to quantitative expression. Carpets change in weight and in thickness of pile when they wear. Both of these changes were studied. Change in thickness appears to be the most useful measure of wear for laboratory tests. A sensitive thickness gage was devised for use with the machine, and is described in the paper.

II. THE MACHINE

1. DESCRIPTION

Figure 1 is a photograph of the carpet wear testing machine. The carpet to be tested is tacked on a wood-covered metal disk or turntable 17 inches in diameter. The turntable is placed over the end of

[1] This machine is similar in principle to one developed for the testing of sole leather. See Hart and Bowker, An Apparatus for Measuring the Relative Wear of Sole Leathers, and the Results Obtained With Leather From Different Parts of a Hide. B. S. Tech. Paper No. 147; 1919.

a vertical shaft which is mounted in a special bearing at one end of a lever so that when a weight is hung at the other end of the lever the carpet is brought to bear with equal vertical force against each of two leather-faced[2] pulleys. The lever arms are approximately balanced, and the leverage ratio is 6 so that the vertical force against each pulley is three times the applied weight.

The pulleys are 15 inches in diameter and 2 inches wide. They are spaced 11 inches from center to center and located equidistant from the center of the turntable. The driving pulley, at the left in the photograph, is rotated by a motor through a suitable speed reducer. The speed of this pulley may be varied by changing the speed of the motor. The free pulley, at the right in the photograph is free to rotate on the shaft of the driving pulley. A brake drum, 12 inches in diameter and 2 inches wide, is fastened to the free pulley. A leather brake belt passing over this drum has one end fastened to a spring balance while a weight is suspended on the other end. The braking torque, which is the difference between the weight and the reading of the spring balance multiplied by the radius of the brake drum may be varied by changing the weight.

2. THEORY

When the machine is in operation the driving pulley, which is rotated by the motor, causes the turntable to rotate and this in turn drives the free pulley. By a suitable combination of speed of turntable, vertical force against each pulley, and braking torque on the free pulley the forces on the pile of the carpet, which is mounted on the turntable, may be controlled. The pulleys will exert a given downward force on the carpet which is determined by the weight on the lever. The frictional force between the driving pulley and the carpet depends upon the coefficient of friction and the normal force, and is great compared to the resisting force produced by friction in the bearings. Consequently, there will be no appreciable slipping of the driving pulley on the carpet when the brake is unloaded. To produce slipping a definite resisting torque is applied by means of the brake. A slight twisting action is produced on the pile of the carpet because of the fact that the carpet is rotating in a plane perpendicular to the plane of rotation of the pulleys. The forces acting on the carpet are, therefore, a vertical force, a horizontal force acting in one direction at one pulley and in the opposite direction at the other, and a rotary motion, all accompanied by slipping. Thus the bending, twisting, slipping, and compression of the pile which takes place when carpets are walked upon is simulated.

The vacuum cleaner shown in Figure 1 is run continuously during the test. It removes the abraded material which has been found to affect the result if allowed to accumulate. It also serves to keep the carpet approximately at room temperature by drawing a considerable volume of air over it. The inlet just touches the pile of the carpet at the beginning of the test.

3. TEST PROCEDURE

Circular samples 15 inches in diameter are cut from the carpet to be tested. These samples are conditioned at a temperature of 70° F.

[2] The leather used on the pulleys is 2-inch belting conforming to the requirements of U. S. Government standard specification No. 37, Circular of the Bureau of Standards No. 148.

and relative humidity of 65 per cent for at least four hours before the test. A specimen is tacked on the turntable which is then put in place on the machine. The weight at the end of the lever is made equal to one-third of the desired downward force on the carpet in contact with each pulley. Because of the difference in the diameters of the brake drum and the free pulley the effective load on the brake is one and one-fourth times the desired horizontal force on the pile of the carpet. The number of revolutions made by the turntable is obtained by means of a revolution counter.

Two methods were employed to measure the rate of wear on the carpet. The first method consists in collecting the material worn off, which is conditioned and weighed. The weight of material removed

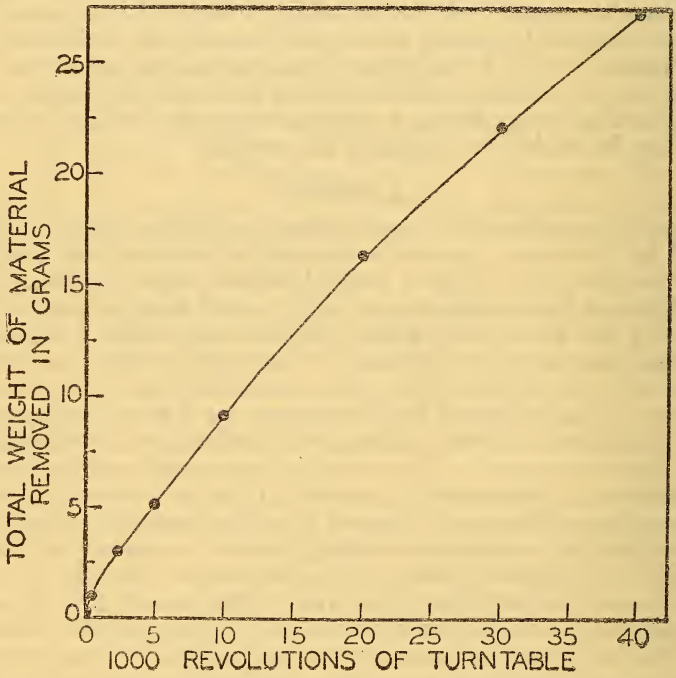

FIGURE 2.—*Results of a test showing the total weight of material removed*

plotted against the total number of revolutions of the turntable gives one measure of the rate of wear on the carpet. The material removed is very light and must be weighed on an analytical balance. Furthermore, it must be collected in a rather large bag which is attached to the vacuum cleaner. Because of the bulky bag the weighing is awkward and the consistency of results depends to a great extent upon thorough conditioning. Although a plot showing the weight of material removed against number of revolutions of the turntable (fig. 2) gives an indication of the rate of wear of the carpet, it does not show when the pile of the carpet is completely worn off, because the base of the carpet starts to wear when the pile is badly worn. The weighing of the abraded material does not appear to be as satisfactory a method of judging the wear as the second method tried.

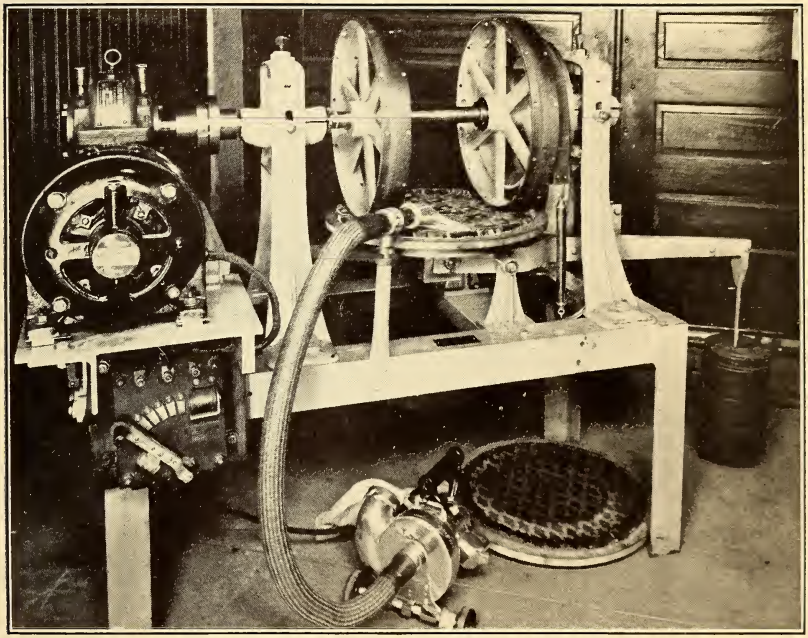

FIGURE 1.—*Carpet wear testing machine*

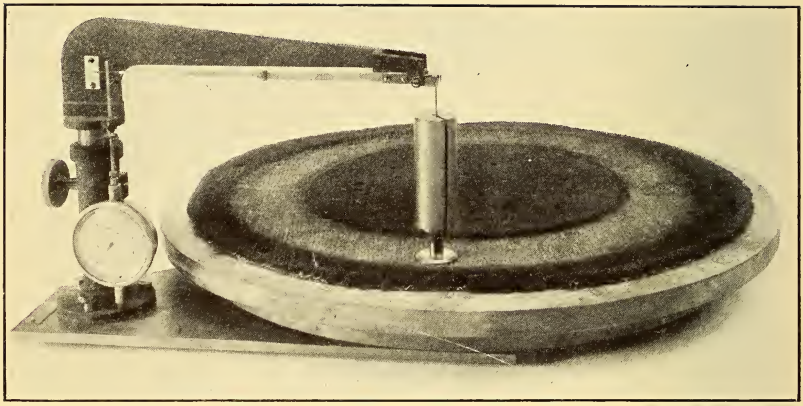

FIGURE 3.—*Gage for measuring thickness of carpet*

The second method consists in measuring the thickness of the carpet at regular intervals with a special thickness gage which is shown in Figure 3. A cylindrical foot 1 inch in diameter and carrying a net weight of 0.59 pound, which is eqivalent to 0.75 lb./in.^{2}, rests on the pile. This compresses the pile an amount which depends upon the density of pile and upon the stiffness of the pile fibers. The resistance to compression due to stiffness of the pile fibers may be considerable before wear, but after a few revolutions of the turntable under the desired downward force it becomes negligible. Therefore thickness measurements taken after a few revolutions give an accurate indication of the amount of pile in the carpet or pile density. It also gives a definite indication when all of the pile is worn off, namely, when the thickness of the carpet is equal to the thickness of the base where all of the pile has been pulled out. The decrease in carpet thickness gives an indication of the apparent initial wear and of the wear of the carpet. Thickness measurements were taken before wear and after a given number of revolutions of the turntable at 8 points, spaced 45° apart on the worn portion of the carpet. The average of these 8 measurements is the thickness of the carpet referred to in Figures 4 to 8, inclusive.

Some carpets wear more rapidly where the pile fibers are bent across the shots than where they are bent parallel to the shots. For this reason it is not considered satisfactory to test more than one specimen at a time which otherwise could be done by tacking sectors of different carpets on the turntable. Carpets which wear unevenly should have thickness measurements made at 16 points, spaced 22.5° apart on the worn portion of the carpet, instead of at only 8 points.

III. PERFORMANCE TESTS

In order to bring out the characteristics of the carpet wear testing machine, a series of tests were made on specimens taken from the same velvet carpet. An analysis of this carpet gave the following results:

Wires per inch		9		
Binders per inch		16		
Stuffers per inch		32		Per cent
Weight of carpet	oz./yd.^{2}	53	or	100
Weight of pile	do	20. 1	or	38
Weight of stuffers	do	16. 5	or	31
Weight of binders	do	6. 4	or	12
Weight of shots	do	10. 0	or	19

Pile is all wool.

1. DUPLICATION OF RESULTS

Three specimens from the same carpet were tested, using a downward force of 150 pounds on the carpet at each pulley, a brake load of 15 pounds, and a turntable speed of 80 r. p. m. The results are shown graphically in Figure 4, where the open circles, solid circles, and solid squares denote the results for the three specimens, respectively. The broken horizontal line represents the thickness of the base of the carpet where all of the pile has been pulled out.

The results for the three tests are in good agreement. A mean curve is drawn through these points which is used for comparison with tests made under different test conditions.

2. DOWNWARD FORCE ON CARPET

In Figure 5 the curve through the solid circles is the mean curve of Figure 4. The curves through the solid triangles and solid squares represent the results for tests in which the downward force at each pulley was changed from 150 to 75 and 202.5 pounds, respectively, while the brake load and speed of turntable were kept constant at 15 pounds and 80 r. p. m., respectively. These curves show that the rate of wear of the carpet increases rapidly with the downward force.

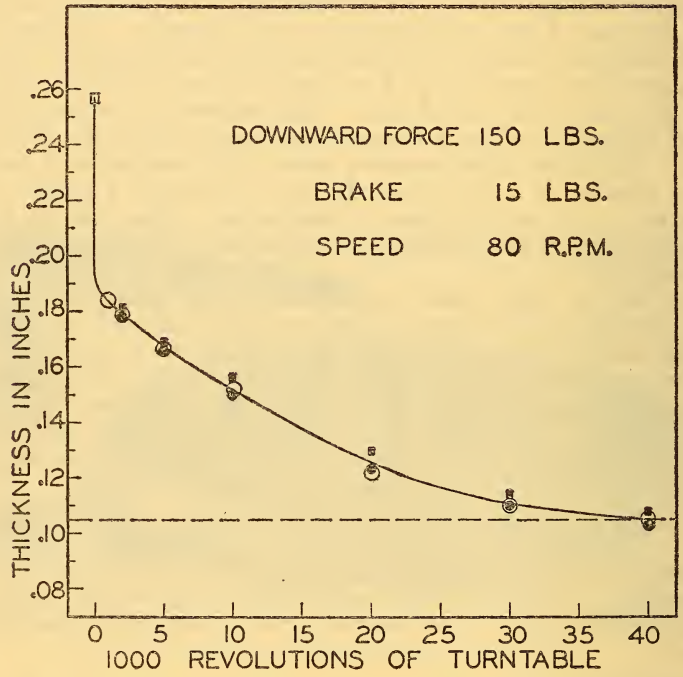

FIGURE 4.—*Results of three tests of same carpet*

3. BRAKE LOAD

In Figure 6 the curve through the solid circles is the mean curve of Figure 4. The curves through the solid triangles and solid squares represent the results for tests in which the brake load was changed from 15 to 0 and 25 pounds, respectively, while the downward force and speed of turntable were kept constant at 150 pounds and 80 r. p. m., respectively. These curves show that the rate of wear of the carpet increases slightly with the brake load.

4. SPEED OF TURNTABLE

In Figure 7 the curve through the solid circles is the mean curve of Figure 4. The curves through the open circles, solid triangles, and solid squares represent the results for tests in which the speed of the turntable was changed from 80 to 30, 60, and 100 r. p. m., respectively, while the downward force and brake load were kept constant at 150 and 15 pounds, respectively. It will be noted that

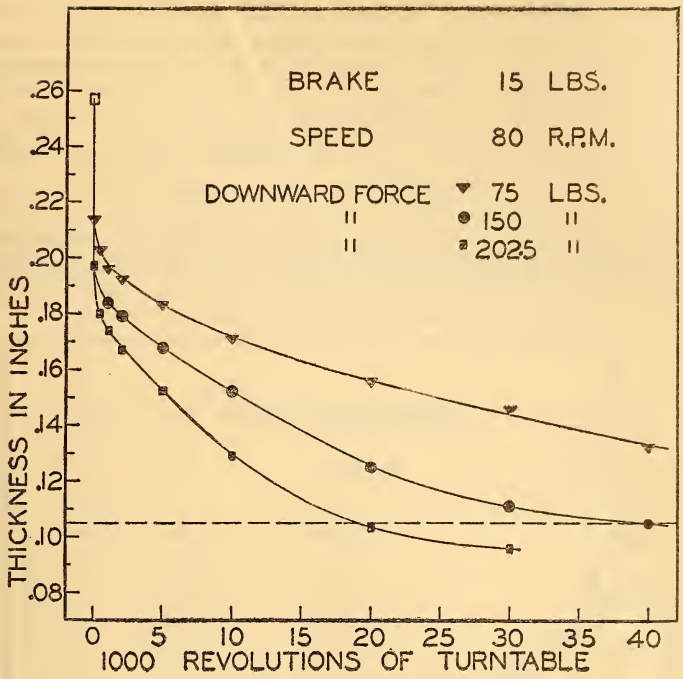

FIGURE 5.—*Results of three tests showing the effect of downward force on the wear of the carpet*

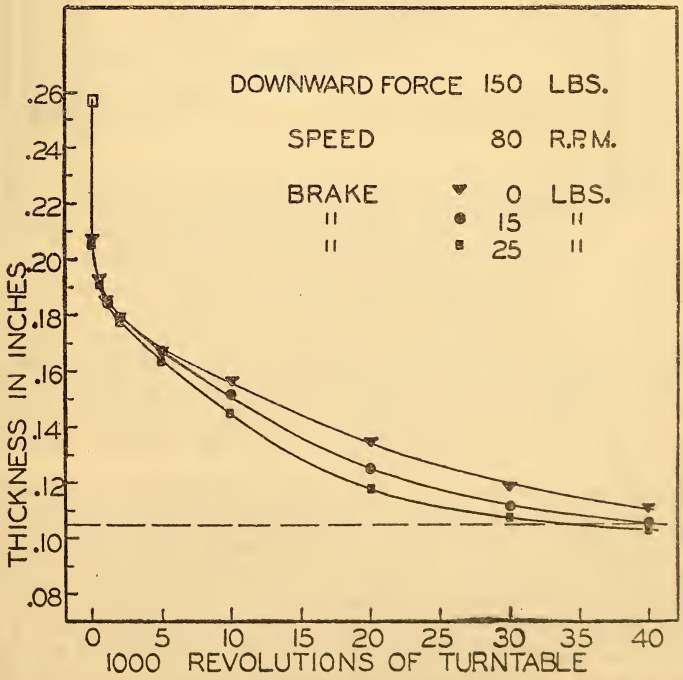

FIGURE 6.—*Results of three tests showing the effect of brake load or slipping on the wear of the carpet*

the wear per revolution is greater as the speed of the turntable is increased. The work expended on the carpet per second is proportional to the speed, so that the carpet becomes warmer and drier as the speed is increased, which may account for the results obtained. It may, consequently, prove advisable to reduce the speed of test below 80 r. p. m., although this will lengthen the time required for a test.

5. APPARENT INITIAL WEAR

In Figure 8 is shown on a larger scale the rapid decrease in thickness of the carpet during the first 2,000 revolutions of the turntable. The curves through the solid triangles, dots, and solid squares cor-

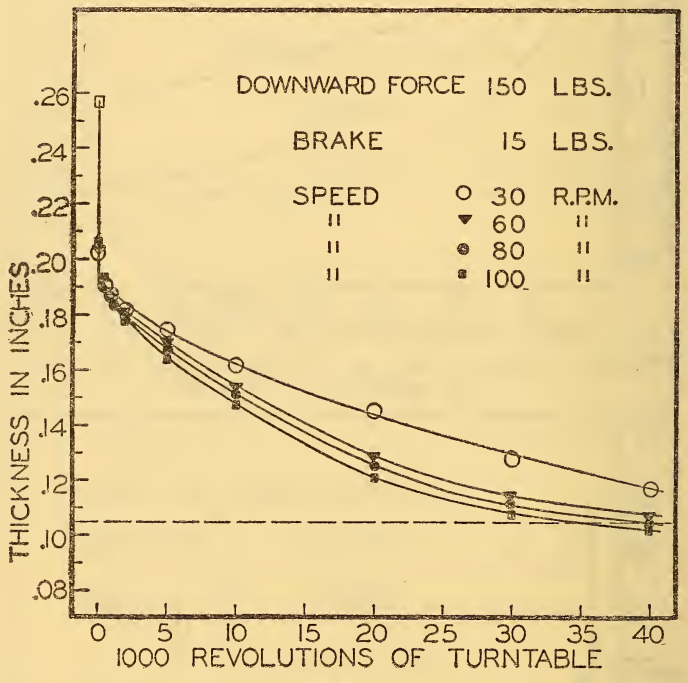

FIGURE 7.—*Results of four tests showing the effect of speed of the turntable on the wear of the carpet*

respond to a downward force on the carpet at each pulley of 75,150, and 202.5 pounds, respectively. The scattering of the observed points on the middle curve is due to variations produced in the rate of wear by the various speeds of the turntable and the various loads on the brake.

It is to be noticed from Figure 8 that a rapid decrease in thickness takes place during the first 100 revolutions of the turntable. This may be attributed in part to the removal of loose or weak pile fibers by the vacuum cleaner. The mos important cause, however, probably is a decrease in stiffness of the pile fibers. That more material is removed from the carpet at the beginning of a test is shown by the curve for Figure 2. An examination of the material shows a greater percentage of long pile fibers removed during the first

500 revolutions than during the interval from 30,000 to 40,000 revolutions. A microscopic examination of the fine material shows that it is practically all wool; that is, pile fibers worn into small shreds.

6. WEAR INDEX

Until wear tests have been made on many carpets of varying grades and constructions, it is not possible to select a single quantity as the wear index. It is suggested, therefore, that a curve similar to the one shown in Figure 4 be determined for each test. If after a sufficient number of curves have been obtained it is found that none

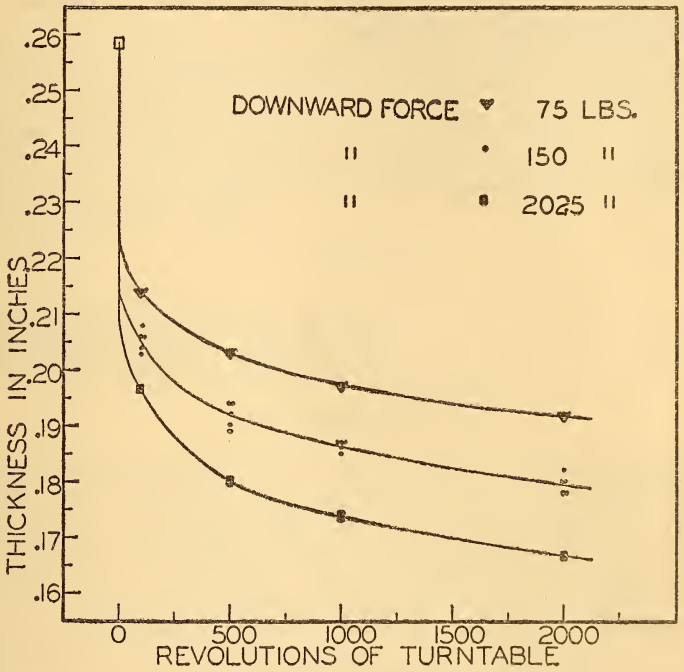

FIGURE 8.—*Results showing the apparent initial wear of the carpet*

of these curves intersect, then either (*a*) the thickness of the pile after a given number of revolutions of the turntable or (*b*) the number of revolutions of the turntable after the pile is worn down to a given thickness may be used as the wear index.

IV. SUMMARY

A machine is described with which samples of carpets and similar floor coverings can be subjected to definite wearing forces that can be varied at will under controlled conditions. The forces are chosen to resemble those which bear on a carpet when it is walked upon. Using a downward force of 150 pounds on each pulley of the machine, a brake load of 15 pounds and a speed of 80 r. p. m. of the turntable, carpets can be worn out in the course of one day. Performance tests show that the machine gives reproducible results.

The decrease in thickness of the pile of the carpet during the test is found to be a more convenient criterion of wear than decrease in weight. A thickness gage for use with the machine is described.

The machine can be used to test the relative durability of carpets under definitely specified conditions. Whether the results are a satisfactory measure of probable relative durability of carpets in service has not been determined.

The machine should be useful for studies of the effect of various factors on carpet wear and for studies of the relation between composition and construction of carpets and their resistance to wear.

Working drawings for the construction of the machine may be obtained from the National Bureau of Standards on request.

WASHINGTON, August 12, 1930.